Ay 192 — Problem Set 1

Due Wednesday October 13th, 1998

Problem 1. We've just built a 6.5-meter telescope with a 1.2-m large Cassegrain secondary. (a) Plot (logarithmically!) the fraction of total radiation contained in a circular aperture as a function of aperture size (radius). Do this for wavelengths of 5500 Å and for 20 μ. What is the 50% encircled energy diameter? The 95% diameter?

(b) Convolve (hint — do this numerically!) the visible (5500 Å) Airy function with Gaussian seeing profiles of 1.0" FWHM and 0.5" FWHM. What are the resulting 50% and 95% encircled energy diameters?

(c) How different are the Airy functions for the 6.5-m with a central obscuration versus one without? I.e. what is the effect of the secondary on the image profile? (Hint: plot this as a ratio of the two Airy functions versus radius).

Problem 2. The concept of Detective Quantum Efficiency (DQE) is a very important one in astronomy - it can sometimes mean that a detector with poor raw quantum efficiency can beat out one with a better raw Q.E. if its noise characteristics are better.

Given the two detectors described in class - a photomultiplier and a CCD - compute their DQE (detective quantum efficiency) as a function of time for the observation of an astronomical source (call it a quasar) of 23rd magnitude in a 1500Å bandpass at V and with the Mt. Hopkins 1.2-m telescope (which has a 0.3-m secondary). The sky brightness at V is approximately 21.5 magnitudes per square arcsecond. Assume that the aperture you need to use is 5 arcseconds in diameter.

Assume that the phototube has a dark rate of 0.05 count per second and a raw quantum efficiency of 40%. Assume that the CCD has a readout noise figure of R=10 electrons RMS, dark noise at the rate of 0.005 counts per second and a raw quantum efficiency of 80%. Do the below calculation for the CCD assuming that it has square pixels of 0.66" diameter (the real case on our 1.2-m).

Plot the DQE as a function of the log of the integration time from 0.1 sec to 10000 seconds for both detectors. Remember that

$$DQE \ = \ ((S/N)_{out}/(S/N)_{in})^2$$

Now do the same calculations for the case of "spectroscopy" in a 10Å bandpass (assume 2.5 Å per pixel, which, again, is similar to what we use at Mt. Hopkins).

In each case, how long do you have to integrate to achieve a S/N of 100?

(Hint: Be sure to define input S/N and output S/N early on. If we talk about the input S/N as the statistical noise in the signal from the object (O/Sqrt(O)), then you derive the DQE for the whole system. Remember that for a real observation you also need to make a measurement of the sky so it can be subtracted! —- That's going to add noise somewhere.)

Problem 3. You find a lens in a surplus shop and measure its surfaces. Both appear to be spherical. One side has a radius of curvature of 10 cm and the other 20 cm. What's the focal length of the lens? (Hint: what else do you need to assume? How can you test this assumption?)